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A B. CONNER, DIRECTOR,
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PRODUCTIVE ENERGY OF CERTAIN FEEDS AS MEASURED BY PRODUCTION OF FAT AND FLESH BY GROWING RATS

G. S. FRAPS

Division of Chemistry

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

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Previous work with chickens showed that the energy values of feeds were very nearly in proportion to the digestible nutrients. Experiments were made with a different kind of animal—white rats—to see how the energy was utilized by them.

Beans, casein, cottonseed oil, kafir, oatmeal, starch, wheat flour, wheat bran, wheat gray shorts and yeast were studied. The gains of energy were ascertained by analysis of the rats for protein and fat.

Differences in the energy values of different kinds of feeds were due chiefly to differences in digestibility and to a much less extent to differences in the utilization of the digested nutrients.

Rats gained less than chickens during the period of the experiment, used larger percentages of the food for maintenance and smaller percentages for storage of fat and flesh. In spite of these differences, the energy values of the digested nutrients as measured by rats were nearly the same as when measured by means of chickens.

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PRODUCTIVE ENERGY OF CERTAIN FEEDS AS MEASURED BY PRODUCTION OF FAT AND FLESH BY GROWING RATS

By G. S. Fraps, Chief, Division of Chemistry

Comparisons of the energy values of a number of feeds have been made by measuring the production of fat and flesh by growing chickens (7, 9, 10). These investigations have shown that while the energy values of different kinds of feeds may be widely different, the energy value of equal quantities of digestible nutrients as a rule are fairly uniform. It is desirable to know whether or not other animals utilize energy of feed to the same extent as chickens. For this reason comparisons of the energy values of feeds with corn meal have been made with growing rats similar to those made with chickens, the results of which are presented here.

Procedure

The procedure used is similar to that used for chickens (10). The feeds to be tested were compared with corn meal fed in standard rations. Rats were selected soon after weaning and distributed in 5 groups as nearly equal in weight, sex and otherwise as possible. The rats of one group were analyzed at once and the four others put upon the experimental rations. The number of rats desired could not all be secured at the same time, but they were fed in similar groups and except for experiments A, D and B, for the same number of days. The rats were fed individually in separate cages, weighed weekly, and killed at the end of the period, usually 28 or 35 days. The intestinal contents were removed and in most of the tests the rat was placed in a closed fruit jar, heated at 15 pounds pressure for three hours in an autoclave, allowed to cool overnight and ground in a food chopper with the addition of 3% filter paper to absorb the liquids. Protein ($N \times 6.25$) was determined on 3.5 gram samples by the Kjeldahl-Gunning method. Fat was determined on 4 gram portions by extracting with ether after drying under reduced pressure at 100° C., and grinding in a mortar. The energy content was calculated by the use of the factor 5.60 calories per gram for protein and 9.35 for fat (5), which previous work with chickens has shown to give the same number of calories as combustion in a bomb calorimeter.

In Experiment A, some of the rats were prepared by drying in a vacuum desiccator over sulphuric acid, extracting with ether, and drying the residue. With use of a bomb calorimeter the heat of combustion was determined in the ether extract and in the dried ground residue. The method was found to be too laborious, so that the procedure was abandoned and analysis made of the rats ground up as described above. Analyses were made of the rats in some of the first experiments without

Table 1. Percentages of Constituents of rations used in Exp. A. O. and B.

	Corn Meal Exp. A	Kafir Exp. A	Wheat Gray Shorts Exp. A	Wheat Bran Exp. A	Corn Meal Exp. O	Wheat Bran Exp. O	Oat Meal Exp. O	Beans Exp. O	Corn Meal Exp. B	Graham Flour Exp. B	Wheat Bran Exp. B	Flour Exp.B
Salt mixture	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Sodium chloride	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	--
Cod liver oil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Brewers yeast	8.0	8.0	8.0	8.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Irradiated yeast	--	--	--	--	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Casein	10.0	9.4	12.1	9.6	11.3	10.3	2.0	4.9	4.5	7.7	10.0	9.1
Cottonseed oil	--	2.5	14.4	20.7	9.1	18.9	4.0	10.6	9.2	8.6	18.7	9.9
Corn meal	76.0	--	--	--	67.6	--	--	--	75.2	--	--	--
Kafir	--	74.1	--	--	--	--	--	--	--	--	--	--
Wheat gray shorts	--	--	60.5	--	--	--	--	--	--	--	--	--
Wheat bran and screenings	--	--	--	55.7	--	--	--	--	--	--	--	--
Wheat bran (breakfast food)	--	--	--	--	--	38.8	--	--	--	--	40.3	--
Starch	--	--	--	--	--	20.0	--	20.0	--	--	20.0	--
Oat meal	--	--	--	--	--	--	82.0	--	--	--	--	--
Navy beans, cooked	--	--	--	--	--	--	--	52.5	--	--	--	--
Graham flour	--	--	--	--	--	--	--	--	72.7	--	--	--
Wheat flour	--	--	--	--	--	--	--	--	--	--	--	70.0

previous cooking. There is no reason to think the results were different but the cooked rats were more easily prepared for analysis.

Rats in Experiments A and O were fed from 42 to 68 days, those in set B from 60 to 68 days, in such a way as to equalize the rats on each ration and have the same number of rats on all 4 rations fed the same number of days. In the other experiments, all the rats in the same experiment were fed the same number of days, either 28 or 35. Metabo-

Table 2. Percentage composition of feeds and their effective organic constituents

Laboratory Number	Name of Feed	Protein	Ether extract	Crude fiber	Nitrogen free extract	Water	Ash	Effective organic constituents
43636	Beans, navy (cooked)	24.07	1.70	5.50	61.77	2.93	4.03	89.67
51950	Casein	83.83	1.56	.14	1.83	9.42	3.22	89.17
52124	Casein	83.05	.43	.17	3.28	9.01	4.06	87.30
59109	Casein	81.31	1.37	.14	2.28	10.33	4.57	86.67
60164	Casein	82.35	1.95	.19	2.55	8.89	4.07	89.29
60672	Casein	82.45	1.78	.22	2.23	9.20	4.12	88.69
62943	Casein	82.33	1.46	.23	1.92	10.57	3.49	87.54
63630	Casein	80.94	.14	.14	5.65	8.87	4.26	86.91
43653	Corn meal	9.84	3.62	1.34	75.45	8.50	1.25	93.44
51960	Corn meal	10.70	2.81	1.06	74.35	9.79	1.29	91.37
52141	Corn meal	10.50	2.96	1.02	74.28	9.92	1.32	91.44
62938	Corn meal	10.20	4.34	1.48	71.18	11.49	1.31	91.15
63631	Corn meal	10.05	4.20	1.31	72.00	11.22	1.22	91.50
43055	Corn meal	11.08	5.93	1.63	69.21	10.54	1.61	93.63
59686	Corn meal	9.50	3.36	1.08	73.39	11.71	.96	90.45
60168	Corn meal	9.92	4.46	1.37	71.44	11.47	1.34	91.40
60676	Corn meal	9.81	4.16	1.23	70.71	12.90	1.19	89.88
51963	Flour, patent	12.13	.79	.22	74.40	11.90	.56	88.31
44490	Flour, white	10.38	.98	.39	75.50	12.27	.48	88.09
44486	Flour, whole wheat	12.59	1.90	2.28	69.50	12.01	1.72	86.37
43057	Kafir, white	12.04	2.57	1.87	72.42	9.88	1.22	90.24
43609	Oatmeal	15.46	5.81	1.56	65.62	9.78	1.77	94.15
52123	Starch, corn	.58	.23	.17	88.46	10.45	.11	89.56
51952	Starch, corn	.64	0	.14	88.28	10.85	.09	88.92
60165	Starch, corn	.55	.14	.18	88.36	10.71	.06	89.23
60673	Starch, corn	.65	.05	.23	86.16	12.81	.10	86.92
59687	Starch, corn	.27	.08	.10	87.70	11.76	.09	88.15
62942	Starch, corn	.59	.18	.17	86.20	12.78	.08	87.20
63629	Starch, corn	.43	.04	.17	87.08	12.23	.05	87.60
44488	Wheat bran, Kelloggs	12.59	2.03	9.16	62.13	6.14	7.95	79.29
43635	Wheat bran, Kelloggs	12.86	2.21	8.97	63.76	4.30	7.90	81.59
43056	Wheat bran	15.70	4.35	10.79	54.64	7.97	6.55	80.13
51961	Wheat bran	18.68	4.28	10.17	50.88	9.15	6.84	79.19
59669	Wheat bran	18.36	4.17	9.41	50.47	11.73	5.86	78.21
62941	Wheat bran	19.48	3.25	10.09	49.72	11.04	6.42	76.51
43054	Wheat gray shorts	18.16	4.26	5.42	57.93	10.16	4.07	85.68
51962	Wheat gray shorts	19.15	4.30	7.08	55.74	8.88	4.85	84.57
62939	Wheat gray shorts	15.21	2.87	5.91	59.05	10.81	6.15	82.72
58603	Yeast, brewers	43.92	1.09	4.90	37.69	4.48	7.92	84.06
60166	Yeast, brewers	53.50	.50	2.94	27.21	7.35	8.50	81.84
60674	Yeast, brewers	52.43	.69	6.72	27.19	4.93	8.04	81.17
62940	Yeast, brewers	51.19	.97	.37	35.54	4.44	7.49	88.91
63627	Yeast, brewers	51.18	.81	2.80	34.40	3.57	7.24	87.40
51951	Yeast, irradiated	47.78	.75	1.02	34.52	7.64	8.29	83.99
59685	Yeast, irradiated	47.42	1.22	.65	36.46	7.02	7.23	86.63
60167	Yeast, irradiated	47.70	1.16	1.17	35.89	6.92	7.16	86.20
60675	Yeast, irradiated	48.25	1.22	6.37	30.86	6.36	6.94	81.86
62944	Yeast, irradiated	48.46	1.37	2.02	35.97	5.28	6.90	87.51
63628	Yeast, irradiated	49.47	1.31	3.60	33.90	4.74	6.98	86.32
51954	Yeast, non-irradiated	47.25	1.19	1.08	34.97	7.57	7.94	84.90

lizable energy was calculated by use of the factor 4.2 cal. per gram for the effective digestible nutrients as was done with chickens (10, 11).

Details and Data of the Work

The rations used in Experiments A, O and B are given in Table 1 and were planned to furnish approximately equal amounts of productive energy. The standard corn meal ration used in the other experiments was composed of 50 per cent corn meal, 20 per cent casein, 19.8 per cent starch, 5.0 per cent brewers yeast, one per cent each of irradiated yeast and cottonseed oil, tricalcium phosphate, calcium carbonate, and salt, .02 per cent cod liver oil. The quantities of the test feeds which replaced the corn meal are shown in Table 7. Chemical analyses were made of all the feeds and also of the mixed rations. The percentage composition of the feeds and their effective organic constituents are given in Table 2. As in previous work, the percentage of effective organic constituents is the percentage of protein plus the percentage of nitrogen-free extract plus the percentage of fat multiplied by 2.25.

Digestion experiments with rats were made on all the rations except those used in Experiments A, O, and B, usually two digestion experiments being made on each ration. The effective digestible nutrients of each ration as calculated from the average of the digestion experiments and the chemical analyses of the rations, are given in Table 7.

The average live weights, percentage of protein and fat, and calories per 100 grams of rat, as well as other data, are given in Table 3. The averages are made from the data for each individual rat. Variations in fat content of the rats are shown in Table 4. Wide variations are to be seen, especially with wheat gray shorts in Exp. 9, in which the fat content of the rats ranged from 6.82 to 22.62 per cent. In spite of these variations the productive energy calculated from the results, as shown in Table 8, did not vary widely.

Calculation of Maintenance Requirements of the Rats

This work is a comparison of the energy values of other feeds as compared with that of corn meal, but it is necessary to calculate the maintenance requirements in terms of productive energy used for maintenance by the rats in the groups compared.

For the purpose of the comparison, the productive energy of corn meal and of the standard ration was assumed to be 3.00 calories per gram of effective digestible constituents. The value used for corn meal is the same as that found to be correct for chickens (9). From the work reported on chickens (9) the other constituents of the basal ration appeared to have equal values to those of corn meal. It is recognized that these values are assumptions which may not be exactly correct, but some assumption had to be used in order to make the calculations. It is reasonable to suppose that the cells of the body of the rat are not widely different from those of the chicken, so that differences in the

Table 3. Average composition, weight and calories per 100 gm for rats

	No. averaged	Live wt. at start gm	Live wt. at end gm	Empty wt. at end gm	% empty wt. of live wt.	Wt. after preparation gm	Protein %	Fat %	Cal. per 100 gm
Exp. O									
Preliminary rats									
Calories per 100 gm			155.3						
Corn meal ration	6	39.9	186.6	183.4	98.26	180.0	19.59	17.00	269.8
Kellogg's bran ration	8	39.6	169.5	164.4	96.88	162.0	19.34	16.48	263.5
Oatmeal ration	8	39.5	172.5	168.7	97.76	165.1	20.15	14.39	248.6
Cooked navy beans ration	8	38.7	155.7	151.2	97.00	148.1	19.68	12.32	226.6
Exp. B									
Preliminary rats									
Calories per 100 gm			155.3						
Corn meal ration	8	41.4	177.8	173.8	97.77	177.1	20.11	15.84	261.9
Graham flour ration	7	41.5	177.8	174.7	98.16	176.5	20.77	14.56	253.6
Kellogg's bran ration	8	40.0	173.3	170.2	98.15	172.5	19.23	17.94	276.5
Patent flour ration	8	41.1	177.7	174.9	98.37	175.6	20.11	16.17	265.0
Exp. 1									
Preliminary rats	6		40.7	38.7	94.97	39.1	18.624	8.11	181.2
Calories per 100 gm			172.1						
Corn meal ration	6	40.4	153.4	148.5	97.03	146.3	20.067	12.91	234.2
Wheat bran ration	6	40.9	126.6	118.9	93.93	118.6	21.065	6.62	181.2
Wheat gray shorts	6	39.9	145.4	138.0	95.00	137.2	20.739	7.92	191.4
Patent flour ration	6	40.3	135.0	131.1	97.16	130.5	20.860	8.39	196.5
Exp. 2									
Preliminary rats	6		38.7	37.8	97.68	38 3	18.379	9.82	195.8
Calories per 100 gm			191.3						
Corn meal ration	6	38.8	155.5	150.7	97.00	150.7	20.846	8.34	196.0
Starch ration	6	38.8	145.1	140.1	96.64	137.2	20.082	11.80	224.0
Casein ration	6	38.9	141.5	136.7	96.62	135.1	20.525	10.00	208.4
Cottonseed oil ration	6	38.5	162.1	157.5	97.17	158.0	20.275	11.58	223.0
Exp. 3									
Preliminary rats	6		36.2	34.1	94.03	31.5	18.010	9.33	189.2
Calories per 100 gm			177.9						
Corn meal ration	6	38.0	183.3	172.8	94.25	165.1	20.119	12.92	234.7
Cottonseed oil ration	6	37.8	172.3	162.3	94.16	156.9	20.226	13.86	244.1
Wheat bran ration	6	37.3	148.1	134.8	90.95	130.2	21.457	9.71	212.2
Casein ration	5	38.9	152.6	141.1	92.34	135.7	21.465	10.36	218.4

Table 3. Average composition, weight and calories per 100 gm for rats—Continued

	No. averaged	Live wt. at start gm	Live wt. at end gm	Empty wt. at end gm	% empty wt. of live wt.	Wt. after preparation gm	Protein %	Fat %	Cal. per 100 gm
Exp. 6									
Preliminary rats	6		35.8	33.3	92.78	31.1	19.316	7.54	179.8
Calories per 100 gm		166.8							
Corn meal ration	6	35.4	158.7	150.0	94.69	144.4	20.979	11.64	227.6
Starch ration	6	35.7	154.3	147.7	95.74	142.1	20.595	11.65	225.5
Casein ration	6	34.8	147.7	138.2	93.55	132.5	21.033	10.55	217.7
Cottonseed oil ration	6	35.7	162.0	154.0	95.14	148.0	20.540	12.01	228.6
Exp. 7									
Preliminary rats	6		45.7	42.5	92.95	40.5	19.500	10.83	211.6
Calories per 100 gm		196.7							
Corn meal ration	6	45.8	164.8	156.4	94.87	148.7	20.741	11.08	221.0
Starch ration	6	44.9	150.2	142.7	95.15	135.6	20.407	12.03	227.9
Casein ration	6	45.9	157.2	147.5	93.84	139.5	21.257	9.84	215.3
Yeast ration	6	46.3	151.8	140.5	92.62	134.5	21.163	7.69	191.6
Exp. 9									
Preliminary rats	6		37.6	35.9	95.68	33.3	19.686	8.41	190.0
Calories per 100 gm		181.8							
Corn meal ration	6	38.4	149.5	144.9	96.95	135.5	21.880	12.04	236.4
Wheat gray shorts	6	38.4	144.3	137.2	95.14	128.0	21.350	12.64	239.1
Wheat bran ration	6	37.7	134.6	125.6	93.21	118.1	21.749	8.45	202.1
Yeast ration	6	37.9	136.2	127.5	93.60	120.4	21.923	6.83	187.9
Exp. 10									
Preliminary rats	6		40.1	38.0	94.89	36.5	19.424	6.55	171.2
Calories per 100 gm		162.7							
Corn meal ration	6	41.1	152.5	143.0	93.68	134.1	20.744	9.91	198.7
10% Cottonseed oil ration	6	40.7	155.7	145.8	93.65	138.1	20.877	9.12	203.4
20% Cottonseed oil ration	6	40.8	162.3	151.8	93.63	143.8	20.509	10.95	218.5
30% Cottonseed oil ration	6	40.2	132.1	121.9	92.40	115.1	20.050	12.12	226.8
Corn meal ration average (9)	---	---	---	-----	-----	-----	------	12.41	-----

Table 4. Variations in fat as calculated from individual rats

Experiment number and name of ration	No. Averaged	Fat			Average difference %	Standard deviation
		Average %	Maximum %	Minimum %		
Experiment 1						
Corn meal ration	6	12.91	15.70	9.36	2.61	2.91
Wheat bran ration	6	6.62	8.07	5.60	.81	.98
Wheat gray shorts ration	6	7.92	10.20	5.83	1.50	1.88
Patent flour ration	6	8.39	11.80	6.40	1.23	1.83
Experiment 2						
Corn meal ration	6	8.34	10.10	6.97	1.05	1.28
Starch ration	6	11.80	14.81	8.96	1.79	2.35
Cottonseed oil ration	6	11.58	12.78	10.67	.75	.90
Casein ration	6	10.00	12.96	7.23	1.67	2.15
Experiment 3						
Corn meal ration	6	12.92	15.63	9.53	1.49	2.08
Cottonseed oil ration	6	13.86	16.94	11.61	1.95	2.27
Wheat bran ration	6	9.71	11.13	8.08	.88	1.14
Casein ration	5	10.36	11.40	8.37	.80	1.19
Experiment 6						
Corn meal ration	6	11.64	13.11	9.43	1.37	1.61
Starch ration	6	11.65	13.19	10.13	.82	1.05
Casein ration	6	10.55	12.84	8.15	1.57	1.98
Cottonseed oil ration	6	12.01	15.49	7.75	2.20	2.83
Experiment 7						
Corn meal ration	6	11.08	13.80	9.04	1.58	2.00
Starch ration	6	12.03	13.40	10.59	.92	1.13
Casein ration	6	9.84	11.27	8.29	1.08	1.28
Yeast ration	6	7.69	8.90	6.77	.71	.84
Experiment 9						
Corn meal ration	6	12.04	13.02	9.75	1.04	1.29
Wheat gray shorts ration	6	12.64	22.62	6.82	5.15	6.30
Wheat bran ration	6	8.45	10.82	6.45	1.85	2.08
Yeast ration	6	6.83	7.67	5.73	.62	.77
Experiment 10						
Corn meal ration	6	9.91	11.87	8.12	1.30	1.52
Cottonseed oil ration, 10%	6	9.12	10.05	7.78	.61	.84
Cottonseed oil ration, 20%	6	10.95	13.88	9.32	1.15	1.65
Cottonseed oil ration, 30%	6	12.12	13.39	9.34	1.13	.37
Corn meal ration average (7)	---	-----	-----	-----	-----	1.81

utilization of digested energy may not be wide between the two. Any small differences would be eliminated, since the results are comparative, the energy used from feeds tested being compared with that used from corn meal.

As shown in Table 5, the initial energy content of each rat is calculated from the initial live weight and the initial energy per gram as found by analysis of similar rats in the same experiment. The final energy content is calculated from the final empty weight and final energy content per gram of the rats. The productive energy consumed in the

Table 5. Average data and calculation of maintenance requirements for rats

Experiment Number	Average wt. by periods gm.	Initial energy content Cal.	Final energy content Cal.	Gain of energy Cal.	Prod. energy of ration Cal. per gm.	Ration eaten gm.	Prod. energy of feed eaten Cal.	For Maintenance			Effective digestible constituents of ration %
								Total prod. energy Cal.	Prod. energy per period per 100 gm. Cal.	Prod. energy per day per 100 gm. Cal.	
O	108.8	61.9	498.6	436.4	2.604	390.2	1096.8	660.3	602.5	11.24	---
A	92.2	57.0	301.0	244.0	2.190	432.8	995.5	751.5	809.6	15.94	---
B	111.8	64.2	452.7	388.5	2.668	545.4	1570.7	1182.2	1069.5	16.42	---
1	99.0	69.5	347.4	277.9	2.368	291.0	745.0	467.1	471.9	16.85	86.1
2	98.4	74.2	295.7	221.5	2.368	270.4	692.1	470.6	479.2	17.12	86.2
3	110.0	67.6	403.1	335.5	2.307	359.6	895.4	559.9	512.3	14.64	85.3
6	98.4	59.1	339.6	282.1	2.359	318.0	811.0	530.5	542.9	15.51	86.0
7	109.1	90.1	346.3	256.1	2.309	272.3	678.0	421.9	390.0	13.93	84.6
9	106.9	69.8	342.0	272.2	2.532	333.7	844.2	572.1	539.9	15.43	85.7
10	100.1	66.8	278.4	211.6	2.557	277.5	707.6	496.0	495.8	17.71	86.1
Average (10)	103.5			292.6			903.6			15.48	

standard corn meal ration is the grams of the ration eaten, multiplied by the productive energy per gram of the ration, as calculated from its effective digestible nutrients and a value of 3.0 calories per gram of effective digestible nutrients. By subtracting the gain of energy of each rat from the productive energy of the total ration eaten, the productive energy used for maintenance is secured, since, by definition, the productive energy of the ration used for the gain is equal to the gain in energy of the animal. The total calories used for maintenance are divided by the weight by periods and multiplied by 100 to give the calories of productive energy used to maintain 100 grams of rat for the period of the experiment. The latter result divided by the number of days, gives the calories of productive energy used for maintenance per day per 100 grams.

The maintenance requirements are calculated with the use of average weights by weeks. That is to say, the first and last weight for each week were averaged to secure the average weight for that week, and the sum of the average weights for all the weeks was divided by the number of weeks to secure the average weight by periods. This method has been shown with chickens (5) to give more consistent results than the use of the average of the first and last weight of the entire period, and also, so far as productive energy is concerned, to give more consistent results than the use of the surface area. The average productive energy used for maintenance as given in Table 5 ranges from 11.24 to 17.71 calories, with an average of 15.48 calories per day per 100 grams. In terms of metabolizable energy, of which the productive energy is apparently 72 per cent, 21.6 calories per day per 100 grams would be used for maintenance. According to the data of Kibler and Brody (12), female albino rats weighing 112 gms. used 26.7 calories per day measured by oxygen consumed and male rats weighing 119 gms. used 24.2 calories per day for maintenance. The female rats apparently had the same maintenance requirement for weights of from 112 to 185 grams, regardless of weight or surface area, while that of male rats decreased with age, either on a weight basis or a surface basis, up to a weight of about 200 grams.

The results of Kibler and Brody are apparently higher than those here given when compared at 100 grams weight, but if compared at greater weights, they would be the same or lower, depending on the weight selected. If average weight is 100 grams in the work presented, part of the time the rats weighed more than 100 grams and part of the time they weighed less, as can be seen from the average live weights at the start and at the end given in Table 3.

The maximum, minimum and average calories of productive energy requirements for maintenance are shown in Table 6. The standard deviation is low (less than 5 per cent) except with experiments 7 and 9, in which it is appreciably higher, being more than 10 per cent.

Table 6. Average maintenance requirements in productive energy, Calories per kilogram per day, calculated from individual rats, with Standard deviation

Series Number	Feed No.	Maintenance requirements, Calories per kilogram			Standard deviation
		Average	Maximum	Minimum	
28 days					
1	51964	168.5	174.6	158.3	5.6
2	52137	171.2	177.4	161.9	7.0
7	60677	139.3	168.3	125.1	15.2
10	63632	177.1	191.3	167.3	9.3
Average (4)		164.0	177.9	153.2	9.3
35 days					
3	59688	146.4	157.5	136.9	9.7
6	60169	155.1	167.4	144.1	8.9
9	62946	154.3	194.6	124.1	23.2
Average (3)		151.9	173.2	135.0	13.9
Average (all) (7)		158.8	175.9	145.4	11.3

Productive Energy of Rations

The average data and results of the calculation of the productive energy of the rations which were compared with corn meal are given in Table 7. The energy used for maintenance is calculated by multiplying the average weight by periods of each rat by the average calories required to maintain 1 gram of rat as found with use of the corn meal ration for the same experiment as calculated in Table 5. The sum of the calories for maintenance and for gain of energy gives the total productive energy of the quantity of the feed eaten. This sum divided by the quantity of feed eaten gives the calories of productive energy per gram of the ration. The productive energy of the ration is given in the next to last column of Table 7. In Experiments A, O, and B, the four rats in each comparison were fed the same number of days, but all the rats in a group were not fed the same number of days. The maintenance requirements of the rats on the corn meal ration were calculated per day per 100 grams and from this data the maintenance requirements of the other rats were calculated for the number of days each was fed.

In securing the values given in Tables 5 and 7, the maintenance requirements and productive energy were first calculated from the data for each individual rat and then averaged. The results would be slightly different had the maintenance requirements or the productive energy been calculated from the average data.

The average differences from the mean of the productive energy of the rations, and the standard deviations are given in Table 8. The standard deviations are comparatively small, being less than 6 per cent in most of the experiments, except in Experiment 10, with refined cottonseed oil, in which the variations were appreciably larger.

Table 7. Data and calculations for average productive energy of rations and effective digestible nutrients

Lab. No.	Name of ration and percentage of the important feed	No. Aver-	Aver. Wt. by period Gm.	Initial energy Cal.	Final energy Cal.	Gain of energy Cal.	Ration eaten Gm.	Used for Maintenance Cal.	For Gain and Maintenance	Prod. energy of ration Cal. per Gm.	Effective digestible nutrients of ration per 100 Gm.
43635	Wheat bran (38.75)	8	101.6	61.4	434.4	373.0	407.6	658.6	186.0	2.039	---
43609	Oatmeal (82.0)	8	103.5	61.3	417.6	356.3	407.8	668.0	182.8	1.949	---
43636	Cooked navy beans (52.46)	8	95.5	60.1	349.8	289.5	391.5	616.6	184.0	1.543	---
44486	Graham flour (72.72)	7	120.2	64.5	441.1	376.6	481.0	1266.0	1642.6	2.963	---
44488	Wheat bran (40.29)	8	112.9	62.0	474.2	412.2	545.9	1199.6	1611.8	2.941	---
44490	Wheat flour (70.03)	8	117.8	63.8	467.5	403.7	555.8	1249.2	1652.9	3.013	---
51961	Wheat bran (50.5)	6	84.2	70.4	215.0	144.6	292.3	397.6	542.2	1.858	45.7
51962	Wheat gray shorts (50.0)	6	91.7	68.7	263.8	195.1	290.5	432.6	627.7	2.162	62.3
51963	Patent flour (50.0)	6	89.5	69.4	256.0	186.6	257.7	422.2	608.8	2.359	82.2
52123	Starch (50.0)	6	91.0	74.2	314.1	239.9	264.9	428.6	668.5	2.521	84.6
52124	Casein (25.0)	6	90.0	74.4	283.6	209.2	242.1	423.8	633.0	2.617	80.5
	Cottonseed oil (15.0)	6	99.4	73.7	351.4	277.7	233.0	468.4	746.1	3.202	200.9
	Cottonseed oil (20.0)	6	105.5	67.2	397.1	330.0	287.5	540.3	870.2	3.017	213.0
59669	Wheat bran (50.0)	6	92.1	66.3	286.6	220.3	376.3	471.7	692.0	1.834	47.1
59109	Casein (30.0)	5	94.0	69.2	305.7	236.5	325.8	481.3	717.8	2.191	79.9
	Cottonseed oil (20.0)	6	98.8	59.6	249.0	289.4	292.3	523.4	812.8	2.772	208.3
60165	Starch (50.0)	6	92.4	59.5	333.3	273.7	329.3	489.7	763.4	2.317	84.9
60164	Casein (30.0)	6	88.9	58.0	300.2	242.2	306.0	471.1	713.3	2.330	77.3
60673	Starch (50.0)	6	95.9	88.4	325.1	236.7	252.6	374.1	610.8	2.417	84.0
60672	Casein (30.0)	6	102.0	90.2	315.8	225.6	260.9	397.7	623.4	2.393	80.2
60674	Brewers yeast (30.0)	6	101.0	91.1	268.5	177.4	263.8	394.1	571.5	2.166	67.4
62939	Wheat gray shorts (50.0)	6	101.9	69.8	325.9	256.1	379.7	550.5	806.6	2.113	61.7
62941	Wheat bran (50.0)	6	90.3	68.6	252.1	183.5	370.3	487.8	671.3	1.812	47.2
62940	Brewers yeast (30.0)	6	86.8	68.8	238.0	169.2	293.6	468.5	637.7	2.164	65.0
	Cottonseed oil (10.0)	6	101.6	66.2	296.3	230.2	271.5	504.1	734.3	2.749	219.4
	Cottonseed oil (20.0)	6	104.0	66.3	330.6	264.2	250.3	515.8	780.1	3.122	227.8
	Cottonseed oil (30.0)	6	84.0	65.5	274.9	209.5	197.7	416.8	626.3	3.257	218.5

Table 8. Variations in average productive energy of rations as calculated from data from individual rats

Experiment number and names of rations	Productive energy of rations Calories per gram			Average difference	Standard deviation
	Average	Maximum	Minimum		
Experiment 1					
Wheat bran ration	1.86	1.91	1.79	.04	.05
Wheat gray shorts ration	2.16	2.36	2.03	.08	.12
Patent flour ration	2.36	2.49	2.21	.08	.10
Experiment 2					
Starch ration	2.52	2.62	2.44	.05	.07
Cottonseed oil ration	3.20	3.25	3.16	.03	.03
Casein ration	2.62	2.68	2.45	.06	.09
Experiment 3					
Cottonseed oil ration	3.02	3.22	2.76	.14	.18
Wheat bran ration	1.83	1.95	1.77	.05	.07
Casein ration	2.19	2.33	2.04	.12	.14
Experiment 6					
Starch ration	2.32	2.59	2.09	.15	.19
Casein ration	2.33	2.41	2.25	.05	.06
Cottonseed oil ration	2.77	2.96	2.61	.11	.14
Experiment 7					
Starch ration	2.42	2.52	2.29	.06	.08
Casein ration	2.39	2.49	2.30	.04	.06
Yeast ration	2.17	2.30	2.05	.08	.10
Experiment 9					
Wheat gray shorts ration	2.11	2.23	1.95	.12	.13
Wheat bran ration	1.81	1.87	1.74	.04	.05
Yeast ration	2.16	2.30	2.03	.08	.10
Experiment 10					
10% Cottonseed oil ration	2.75	3.05	2.09	.23	.34
20% Cottonseed oil ration	3.12	3.57	2.96	.16	.23
30% Cottonseed oil ration	3.26	4.00	2.71	.38	.48

Calculation of the Productive Energy of the Feeds

The productive energy of the individual feeds compared with corn meal was calculated by the method previously described (9, 10) except for Experiments O, A and B. The grams of effective digestible nutrients of the corn meal ration, multiplied by 3.0 gives its calories of productive energy. The effective digestible constituents of the corn meal multiplied by 3.00 gives its calories of productive energy. The difference between the productive energy value of 1 gram of the corn meal ration and of the ration to be compared gives the effect of substitution of the feed studied. This difference added to the productive energy of the corn meal replaced gives the productive energy of the quantity of the feed used. The productive energies of the effective organic constituents and of the effective digestible constituents were then calculated from the values for the productive energy

In Experiments A, O and B, however, the calculation was slightly different, since the rations were made up to what then appeared to be equal productive energy. Productive energy values per gram of feed

Table 9. Productive energy in terms of feed, effective organic constituents, effective digestible nutrients and metabolizable energy

Name and laboratory number of feed	Exp. No.	Per cent of ration	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
Beans, navy, cooked										
43636	0	--	89.7	75.4	317.0	165	184	219	73	52.0
Casein										
52124	2	25	87.3	80.5	338.1	283	324	352	117	83.7
59109	3	30	86.7	79.9	336.0	156	180	195	65	46.0
60164	6	30	89.3	77.3	325.0	181	203	234	78	55.7
60672	7	30	88.7	80.2	337.0	221	249	276	92	66.0
Average (4)			88.0	79.5	334.0	210	239	264	88	62.9
Corn meal (Standard)										
43653	O	--	93.4	88.0	369.0	260	283	300	100	71.0
43055	A	--	93.6	88.2	369.8	265	283	300	100	71.0
51960	1	50	91.4	86.1	362.0	258	282	300	100	71.0
52141	2	50	91.4	86.2	362.0	259	283	300	100	71.0
59686	3	50	90.5	85.3	358.0	256	283	300	100	72.0
60168	6	50	91.4	86.0	361.0	258	282	300	100	71.0
60676	7	50	89.9	84.6	355.0	256	277	300	100	70.0
62938	9	50	91.2	85.7	360.0	257	282	300	100	71.0
62631	10	50	87.4	86.1	362.0	258	295	300	100	71.0
Average (9)			91.1	86.2	362.1	259	283	300	100	71.0
Cottonseed oil										
——	2	15	225.0	200.9	843.8	690	307	343	114	81.8
——	3	20	225.0	213.0	895.0	520	231	244	81	58.0
——	6	20	225.0	208.3	875.0	364	162	175	58	41.6
——	10	10	102.9	219.4	921.0	450	200	205	68	49.0

Table 9. Productive energy in terms of feed, effective organic constituents, effective digestible nutrients and metabolizable energy—Continued

Name and laboratory number of feed	Exp. No.	Per cent of ration	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
Cottonseed oil (Cont'd)										
———	10	20	118.0	227.8	957.0	541	240	237	79	57.0
———	10	30	129.6	218.5	918.0	492	219	225	75	54.0
Average (6)			170.9	214.7	901.6	510	227	238	79	56.9
Kaffir										
43057	A	--	90.2	83.3	350.0	266	295	319	106	76.0
Oat meal										
43609	O	--	94.1	88.9	373.0	236	251	265	88	63.0
Starch										
52141	2	50	89.6	84.6	355.3	251	280	297	99	70.6
60165	6	50	89.2	84.9	357.0	218	244	257	86	61.1
60673	7	50	86.9	84.0	353.0	239	275	285	95	68.0
Average (3)			88.6	84.5	355.1	236	266	280	93	66.6
Wheat flour										
44490	B	--	88.1	86.7	364.0	252	286	291	97	69
51963	1	50	88.3	82.2	345.0	219	248	266	89	63
Average (2)			88.2	84.5	354.5	236	267	279	93	66
Wheat flour, Graham										
44486	B	--	86.4	80.6	339.0	249	288	309	103	73

Table 9. Productive energy in terms of feed, effective organic constituents, effective digestible nutrients and metabolizable energy—Continued

Name and laboratory number of feed	Exp. No.	Per cent of ration	Effective organic constituents per cent	Effective digestible nutrients per cent	Metabolizable energy Cal. per 100 gm.	Productive energy				
						Total feed Cal. per 100 gm.	Effective organic constituents per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy
Wheat bran mixture (human food)										
43635 (Kellogg's)	O	--	81.6	55.7	234.0	144	176	259	86	62
43056 (Kellogg's)	A	--	80.1	49.1	206.0	185	231	377	126	90
44488 (Kellogg's)	B	--	79.3	55.7	234.0	191	241	343	114	82
Average (3)			80.3	53.5	224.7	173	216	326	109	78
Wheat bran (commercial)										
51961	1	50	79.2	45.7	192.0	119	150	260	87	62
59669	3	50	78.2	47.1	198.0	125	160	265	88	63
62941	9	50	76.5	47.2	198.0	113	148	240	80	57
Average (3)			78.0	46.7	196.0	119	153	255	85	61
Wheat gray shorts										
43054	A	--	85.7	69.9	378.0	250	292	278	93	66
51962	1	50	84.6	62.3	262.0	179	212	287	96	68
62939	9	50	80.7	61.7	260.0	174	216	282	94	67
Average (3)			83.7	64.6	300.0	201	240	282	94	67
Yeast										
60674	7	30	81.2	67.4	283.0	146	180	217	72	52
62940	9	30	88.9	65.0	273.0	101	114	157	52	37
Average (2)			85.1	66.2	278.0	124	147	187	62	45

were used in the final calculations as follows: Wesson oil 5.10, starch 2.34, casein 2.08 and corn meal 2.64 calories. The effective digestible nutrients of the feeds compared with corn meal were calculated from the digestion experiments made on the rations by methods similar to those used for calculating the productive energy, as described above. That is to say, the quantities of total digestible nutrients of the test ration were subtracted from those of the standard corn meal ration and the calculations completed in a way similar to that for productive energy.

Productive Energy of the Feeds

The productive energy of certain feeds, as found in each test, of their effective organic constituents, and of their effective digestible nutrients, when compared with that of corn meal as 100, are given in Table 9. The work here presented reports 30 comparisons on 11 kinds of feed.

The differences in the values of the same feed found in different experiments are greater in some cases than are desirable. The errors of the work on the digestion experiments as well as those which occur in determining the productive energy have some effect on the results for the productive energy. The differences may also be due in some experiments to the amount of energy used for maintenance from the standard corn meal ration being different from that used for maintenance from the test ration compared with it. It is considered, however, that the average values are approximately correct.

The average productive energies of the different feeds range from 124 calories per 100 grams for yeast to 510 for cottonseed oil, compared with corn meal, which usually had a value of about 259 calories per 100 grams.

Variations are to be seen with different experiments on the same kind of feed. If the individual tests are also studied, differences are found in the ability of individual rats to utilize the ration in the same experiment as shown in Tables 6 and 8. Since these differences occur for both the standard ration and the test rations, the average results from diffrent tests of the same feed may be expected to differ. Thus the productive energy of different feeds should be calculated from the results of several experiments, each of which is the average of several individual tests. Tests made on a few individuals may not be correct. When equal quantities of digestible nutrients are compared, the productive energy of the feeds used (Table 9) does not deviate widely from that of corn meal. Rats, and chickens (10), utilize the nutrients which they digest to an equal extent. Differences in the foods are due more to differences in digestibility than to differences in the productive energy of the nutrients digested.

Net Energy Determined Elsewhere

The net energy for rats of beef muscle protein, dextrin, lard and a mixture of the three was reported by Forbes et al. (1), in which the food tested was added to a basal diet. The work was done by respiration

Table 10. Net energy in Calories per gm. as calculated by Forbes. et al. Compared with Texas work

	Beef muscle protein Cal.	Dextrin Cal.	Lard Cal.	Mixture Cal.
Forbes et al.:				
Exp. 1—rats about 100 gm.	1.19	1.72	6.59	4.41
Exp. 1—rats about 240 gm.	1.38	1.99	6.06	4.83
Exp. 2—rats about 100 gm.	1.24	2.15	6.28	4.89
Exp. 2—rats about 200 gm.	1.85	2.25	6.12	5.07
Average (4)	1.42	2.03	6.26	4.80
Average, 1.72 excluded		2.13		
Calculated net energy of mixture				4.56
Productive energy Texas experiments:				
Casein, rats	2.10	----	----	----
Casein, chickens	2.24	----	----	----
Starch, rats	----	2.36	----	----
Starch, chickens	----	2.17	----	----
Cottonseed oil, rats	----	----	5.10	----
Cottonseed oil, chickens	----	----	4.67	----

methods. The values for net energy are summarized in Table 10. The mixture consisted of 62.5% of lard and 18.75% each of dextrin and beef muscle. The net energy value of the mixture calculated from the average net energy value of its constituents as shown in Table 10, would be 4.56 calories per gram. The average value found of 4.80 was not far from this. The results do not justify the claim that the net energy of a mixture must be different from the net energy of the ingredients.

Texas experiments were not made on the same kinds of feeds as used by Forbes et al. but the results for foods of similar classes with rats and with chickens are given in Table 10. The net energy value of beef protein of 1.42 calories per gram was much lower than the 2.10 calories for casein with rats and 2.24 calories with chickens. The value of 2.03 calories per gram for dextrin was lower than the 2.36 calories for starch by rats and 2.17 calories for chickens. These values would be closer if the low value of 1.72 calories per gram obtained in one of the Forbes experiments is excluded, then the average for dextrin would become 2.13 calories per gram. The average value of 6.20 calories per gram with lard is appreciably higher than 5.10 calories per gram for cottonseed oil with rats and 4.67 calories for chickens obtained in the Texas work.

Comparison of Rats and Chickens

Some comparisons of rats and chickens on the corn meal ration are given in Table 11. The chickens on experiment gained more weight in 21 days than the rats gained in 28 to 35 days. The chickens also stored up a much greater proportion of the energy of feed, 57.9 per cent, than the rats, 32.4 per cent, so that the rats used a much greater proportion

Table 11. Comparison of rats with chickens (Bulletin 600) on the corn meal rations

	Rats	Chickens
Period of experiment	28 or 35 days	21 days
Average weight by periods, gm.	104	121
Energy used for gain, per cent	32.4	57.9
Average fat content	12.4	9.7
Standard deviation of fat content	1.8	1.6
Used for maintenance per day per 100 grams, productive energy, Calories	15.5	13.2
Standard deviation for maintenance	1.1	0.9
Used for maintenance per day per 100 grams, metabolizable energy, Calories	21.8	18.2
Standard deviation of productive energy	----	19.6
of rations—wheat bran	.06	.08
Wheat gray shorts ration	.13	.09
Patent flour ration	.10	.09
Starch ration	.11	.12
Cottonseed oil ration	.23	.24
Casein ration	.09	.12
Yeast ration	.10	.12

of their rations for maintenance purposes. The average fat content of the rats was greater, 12.4 per cent, that of the chickens 9.7 per cent, and the fat content was slightly more variable in the rats, the standard deviation being 1.8 compared with 1.6 for the chickens. The average calories of productive energy used for maintenance by the rats per 100 grams was 15.5 calories compared with an average of 13.2 for chickens in one series (5) and 14.2 in another (10), while the metabolizable energy used for maintenance was 21.8 calories compared with 18.2 and 19.6 for the chickens. The average difference in energy used for maintenance was not wide, but seems to be real and not due to variations. The productive energy values of the rations seem to vary a little more with chickens than with rats.

On account of the greater percentage of the ration stored by chickens and the greater gains in weight as well as the fact that a desired number of chickens can be secured at one time more readily than is the case with rats, the chickens seem to be the preferable animal to use in this kind of work.

Comparisons of the average productive energy values secured by use of rats and of chickens are given in Table 12. The productive energy of the total feed and of the effective organic constituents is as a rule higher for rats than for chickens. The utilization of the digested material is best compared on the basis of the productive energy of the digested materials compared with those of corn meal taken as 100. The energy of the digested constituents from cottonseed oil, kafir, wheat flour, wheat gray shorts and yeast is used practically the same by rats and chickens. The differences are not large with starch and wheat bran. The greatest differences are with casein, oat meal, wheat flour and wheat bran mixture (human food). On account of the limited number of experiments with these feeds, no great emphasis can be placed on these differences, with the possible exception of casein. For casein the standard deviation of

Table 12. Comparative productive energy of feeds for rats and chickens

Name of feed	Total feed Cal. per 100 gm.	Effective organic constituents Cal. per 100 gm.	Effective digestible nutrients Cal. per 100 gm.	Rank with effective digestible nutrients of corn meal as 100	In percentage of metabolizable energy	Number of samples
Beans, navy, cooked, rats	165	184	219	73	52	--
Casein, rats	210	239	264	88	63	4
Casein, chickens	224	256	317	105	76	6
Corn meal (standard), rats	259	283	300	100	71	--
Corn meal (standard), chickens	241	264	300	100	72	--
Cottonseed oil, rats	510	227	238	79	57	6
Cottonseed oil, chickens	467	208	237	79	57	6
Kafir, rats	266	295	319	106	76	1
Kafir, chickens	231	254	306	102	73	2
Oatmeal, rats	236	251	265	88	63	1
Oatmeal, chickens	235	248	297	99	71	6
Starch, rats	236	266	280	93	67	3
Starch, chickens	217	245	262	87	62	7
Wheat flour, rats	236	267	279	93	66	2
Wheat flour, chickens	214	243	283	94	68	6
Wheat flour, Graham, rats	249	288	309	103	73	1
Wheat flour, chickens	176	203	276	92	66	2
Wheat bran mixture (Human food), rats	173	216	326	109	78	2
Wheat bran mixture (Human food), chickens	145	184	270	90	64	2
Wheat bran, commercial, rats	119	153	255	85	61	3
Wheat bran, commercial, chickens	100	125	273	91	65	6
Wheat gray shorts, rats	201	240	282	94	67	3
Wheat gray shorts, chickens	144	171	283	94	67	7
Yeast, rats	124	147	187	62	45	2
Yeast, chickens	86	100	188	63	45	2

the 88 calories of the productive energy found for the rats is 22, and for the 76 calories found with chickens is 18. Statistical analysis show that T required for significance is 2.3, while T found is 1.3, so that the difference is not significant.

The digestible nutrients of foods are in general utilized for energy by rats to the same extent as those of corn meal, and as a rule do not deviate widely from that of corn meal. There are some differences, but most of them are not far from the value for corn meal. The digestible nutrients of yeast have a value of 62 for rats and 63 for chickens, compared with corn meal as 100. This low value is probably due to the poor quality of the amino acids present.

The energy value of the effective digestible nutrients of cottonseed oil is 79 compared with those of corn meal as 100 for both rats and chickens, showing that oils are not utilized as well for storage of energy as protein or starch, and that the relative value of fats to carbohydrates is 1.8 instead of 2.25 generally used.

Retention of the Protein

Analyses of the rats, of the rations, and the digestion experiments, furnished data as to the retention of the digestible protein by the rats. These data are summarized in Table 13. The calculations were made from the average data, not for each individual as in the other work here presented, the method of calculation has been described (9). The digestible protein retained by chickens averaged 42.5 per cent as reported in Bulletin 571 (5), and 50 to 56 per cent of the corn meal ration containing about 20 per cent protein in (9) Bulletin 600. With the rats on the corn meal ration, Table 13, it ranged from 32 to 40 per cent. The chickens, therefore, stored higher percentages of the protein than did the rats. This is in accordance with the storage of lower percentages of productive energy by the rats.

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Summary

The productive value of the energy of 11 kinds of feeds in 30 comparisons with corn meal was studied by means of the gain of protein and fat by growing rats. The feeds studied include beans, casein, cottonseed oil, kafir, oatmeal, starch, wheat flour, wheat bran, wheat gray shorts and yeast.

The growing rats used for maintenance an average of 15.5 calories of productive energy or 21.5 calories of metabolizable energy per day per 100 grams.

The average productive energy of the feeds tested ranged from 124 calories per 100 grams for yeast to 510 calories for cottonseed oil. Differences in the energy values of different feeds are due chiefly to differences in digestibility and to much less extent to differences in utilization of the digested nutrients.

Rats gained less weight in 28 to 35 days than chickens in 21 days, stored a smaller percentage of the energy of the food, used a larger percentage of the food for maintenance and contained a higher percentage of fat. The rats used more calories for maintenance per 100 grams than the chickens and stored smaller percentages of the digestible protein. In spite of these differences, the energy values of the digested

Table 13. Protein gained by rat and eaten in ration

Laboratory Number	Name of Ration	Aver. protein in live wt. of rats in beginning %	In Rats			In Ration		Digestible Retained by rats %
			At beginning gm.	At end gm.	Gain gm.	Average gm.	Digestible gm.	
51960	Corn meal (50.0) Exp. 1	17.69	7.15	29.80	22.65	74.06	67.52	33.55
51961	Wheat bran (50.0)		7.24	25.05	17.81	86.05	73.37	24.27
51962	Wheat gray shorts (50.0)		7.06	28.62	21.56	86.69	75.43	28.58
51963	Patent flour (50.0)		7.13	27.35	20.22	67.52	61.95	32.64
52141	Corn meal (50.0) Exp. 2	17.95	6.96	31.41	24.45	68.33	62.08	39.42
52123	Starch (50.0)		6.96	28.13	21.17	54.89	50.05	42.34
52124	Casein (25.0)		6.98	28.06	21.08	106.52	98.01	21.51
-----	Cottonseed oil (15.0)		6.91	31.93	25.02	54.20	48.87	51.20
59686	Corn meal (50.0) Exp. 3	16.93	6.43	34.77	28.34	84.47	75.76	37.41
-----	Cottonseed oil (20.0)		6.40	32.83	26.43	63.22	56.65	46.65
59669	Wheat bran (50.0)		6.31	28.92	22.61	106.27	89.85	25.16
59109	Casein (30.0)		6.59	30.29	23.70	147.91	137.19	17.28
60168	Corn meal (50.0) Exp. 6	17.92	6.34	31.47	25.13	78.39	70.72	35.53
-----	Cottonseed oil (20.0)		6.40	31.63	25.23	68.08	60.95	41.39
60165	Starch (50.0)		6.40	30.42	24.02	66.35	59.97	40.05
60164	Casein (30.0)		6.24	29.07	22.83	142.78	132.24	17.26
60676	Corn meal (50.0) Exp. 7	18.13	8.30	32.44	24.14	66.06	60.21	40.09
60673	Starch (50.0)		8.14	29.12	20.98	50.72	45.48	46.13
60672	Casein (30.0)		8.32	31.35	23.03	120.54	111.38	20.68
60674	Brewers yeast (30.0)		8.39	29.73	21.34	99.56	87.39	24.42
62938	Corn meal (50.0) Exp. 9	18.84	7.23	31.70	24.47	84.36	76.51	31.98
62939	Wheat gray shorts (50.0)		7.23	29.29	22.06	103.16	90.02	24.51
62941	Wheat bran (50.0)		7.10	27.32	20.22	111.16	94.89	21.31
62940	Brewers yeast (30.0)		7.14	27.95	20.81	107.60	92.85	22.41
63631	Corn meal (50.0) Exp. 10	18.43	7.57	29.66	22.09	68.10	62.42	35.39
-----	Cottonseed oil (10.0)		7.50	30.44	22.94	64.75	58.94	38.92
-----	Cottonseed oil (20.0)		7.52	31.13	23.61	60.29	54.90	43.01
-----	Cottonseed oil (30.0)		7.41	24.44	17.03	42.47	38.54	44.19

nutrients as measured by means of rats was nearly the same as when measured by means of chickens.

The productive energy of oil as measured by both rats and chickens was 79 compared with 100 for corn meal. Oil has a value of 1.8 times that of carbohydrates instead of the 2.25 times it is usually supposed to have.

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